Transfer of conditioned fear and avoidance: concurrent measurement of arousal and operant responding

Miguel Rodríguez-Valverde (1), Carmen Luciano (2), Dermot Barnes-Holmes (3)(4), and Mónica Hernández-López (1)

(1) Universidad de Jaén (Spain)
(2) Universidad de Almería (Spain)
(3) Ghent Universiteit (Belgium)
(4) University of Ulster, Coleraine (Northern Ireland, UK)

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Correspondence concerning this article should be addressed to: Miguel Rodríguez-Valverde. Dpto. de Psicología, C5-116. Universidad de Jaén. Campus las Lagunillas, s/n. 23071. Jaén. SPAIN.

ABSTRACT

A reversal design was employed for the analysis of transfer of fear and avoidance through equivalence classes. Two five-member equivalence classes (A1-B1-C1-D1-E1 and A2-B2-C2-D2-E2) were established. Then B1 and C1 were paired with shock (CS+) and served as S^Ds in avoidance training (B2 and C2 were trained as CS-/S^Δs for avoidance). Further avoidance training followed with D1 and E1 (as S^Ds) and D2 and E2 (as S^Δs), with the first presentation of each of these stimuli serving as the first transfer test. Afterwards, aversive conditioning contingencies were reversed: B2 and D2 were paired with shock and trained as S^Ds for avoidance, B1 and D1 were presented without shock (CS-/S^Δs). Transfer was tested again with C1, E1, C2 and E2. This reversal was implemented to allow for the within-subject replication of transfer effects upon changes in the function of only a subset of each class' elements. Avoidance (key presses) and conditioned fear (skin conductance and heart rate) were simultaneously measured. Results show a clear transfer effect for avoidance, with between- and within-subject replications. For physiological measures, transfer effects in the first test could only be imputed on the basis of group-based inferential statistical analysis. Evidence for between-subject replication was weaker, with only a limited proportion of participants meeting the individual criterion for transfer.

Keywords: transfer of functions; stimulus equivalence; fear conditioning; avoidance; skin conductance; heart rate.

Recent behavior-analytic approaches to the study of human anxiety and its disorders (Dymond et al., 2018; Dymond & Roche, 2009; Smith et al., 2020) have emphasized the key role of research on stimulus equivalence and other derived stimulus relations. Specifically, research on transfer (in accordance with equivalence relations) and transformation (in accordance with non-equivalence derived stimulus relations) of conditioned fear and avoidance-evoking functions constitute promising laboratory models for widely observed clinically-relevant phenomena involving fear reactions and avoidance behavior to events and situations with no apparent history of aversive conditioning and no physical similarity to directly conditioned stimuli.

Stimulus equivalence emerges readily in language-able humans after training interrelated conditional discriminations among arbitrary stimuli. For instance, when selecting B1 in the presence of A1 is reinforced (A1-B1), and selecting C1 in the presence of A1 is also reinforced (A1-C1), untrained relations of symmetry (selecting A1 in the presence of either B1 or C1: B1-A1 and C1-A1) and transitivity (selecting C1 in the presence of B1, and vice versa: B1-C1 and C1-B1) will appear in the absence of feedback. When combined symmetry and transitivity relations emerge amongst a set of stimuli, a stimulus equivalence relation is said to have been established amongst these stimuli (Sidman, 1971; Sidman & Tailby, 1982; Sidman, 1994). Research has repeatedly shown that the stimuli belonging to an equivalence class are functionally substitutable, that is, when one of them acquires a function (i.e., is trained to control a new behavior), the remaining elements of the class will have the same function without explicit training (Dougher, 1998; Dougher & Markham, 1996; Dymond & Rehfeldt, 2000). This phenomenon, termed transfer of function, can be illustrated by a description of the study by Dougher et al., (1994), the first experimental demonstration of transfer of both conditioned fear and fear extinction among elements of an equivalence class. Participants were trained in the formation of two equivalence classes. Then they underwent differential aversive conditioning with one element from each class and mild shock as the unconditioned stimulus (UCS). In a subsequent test with other elements from each class, participants showed higher arousal (skin conductance responses, SCRs) to the stimuli belonging to the CS+ class. Using a similar procedure, Augustson and Dougher (1997) provided evidence that avoidance behavior can similarly be controlled by stimuli lacking a direct history of aversive conditioning and negative reinforcement, but in an equivalence relation with an aversively conditioned stimulus. Participants learned to repeatedly press a telegraph key in order to avoid impending shock in the presence of an element from an equivalence class (and not in the presence of an element

from another class). In a subsequent test, they emitted avoidance responses in the presence of stimuli from the same equivalence class as the aversive CS.

A growing number of studies have since replicated and extended these findings regarding the transfer of avoidance-evoking functions with different experimental preparations (see Boldrin & Debert, 2020; Donati et al., 2019; Dymond et al., 2012; Dymond et al., 2014; Dymond et al., 2011; Gandarela et al., 2020; García-Guerrero et al., 2014; Luciano et al., 2013, 2014), as well as their transformation according to relations of sameness/opposition (Bennett et al., 2015; Dymond et al., 2007, 2008; Roche et al., 2008). Some of these studies have been framed under the rubric symbolic generalization instead of the more traditional behavior-analytic terminology of transfer/transformation of functions. Typically, symbolic generalization studies have favored group designs with large samples and a presentation of results based on inferential statistical tests, in line with mainstream research on human fear generalization (see Dymond et al., 2015). While this clearly serves the important purpose of easing communication and connection between otherwise separate research approaches to the same phenomena, the prioritization of group statistical analysis over the behavior-analytic-preferred individual analysis of replication across participants may obscure individual subject variability and yield patterns of results that are actually not representative of the performance of a substantial proportion of individual participants (Sidman, 1960). This is perhaps less evident in studies using signaled avoidance responses as their primary outcome measure, since these are discrete, easy to quantify, and apparently do not show large inherent variability. However, it may constitute a more important problem for studies using psychophysiological responses as their primary proxy of conditioned fear, where statistical significance may be easily achieved with current standard data-analytic strategies (see Ney et al., 2018, for a recent discussion of interpretability and replicability problems derived from current use of inferential statistics for psychophysiological research on fear conditioning). This is relevant, considering that the actual evidence regarding the transfer of fear-conditioned respondents with psychophysiological measures is rather limited.

In addition to Dougher et al.'s (1994) original study, only a handful of articles have been published on the transfer of respondent fear elicitation. Vervoort et al. (2014) repeated Dougher et al.'s (1994) study with a large sample and a between-groups experimental design. The evidence for transfer of fear elicitation was presented only through inferential statistical tests at a group level, rendering it difficult to know whether putative transfer effects were indeed well replicated across participants. An earlier study by Valverde et al. (2009) had extended the findings of Dougher et al. (1994) with a single-group multiple-CS design

including a contingency reversal that allowed for the within-subject replication of the transfer of fear effect. In brief, after the acquisition of differential aversive conditioning and transfer tests, two elements from the original CS+ class were used as CS- and two elements from the original CS- class were used as CS+. Then, the remaining elements from each class were tested, and found to change their function according to the latter contingency arrangement. This study presented its findings both idiographically and at a group level (collapsed across participants). This allowed for the comparison of results with both analytic strategies. For instance, while statistical tests revealed a transfer of function effect both before and after the contingency reversal, the individual analysis showed that only for the first transfer test was this effect attributable to a substantial proportion of participants meeting criteria for differential conditioning and transfer. After the contingency reversal, only a reduced proportion of participants met such criteria.

To date, all published studies reporting evidence of transfer or transformation (Dougher et al., 2007) of fear as measured with psychophysiological responses have relied on a single measure: electrodermal activity (SCRs). It is yet to be seen if these findings can be replicated with other psychophysiological measures typically employed in fear and anxiety research. For instance, López-Medina et al. (2016) found no evidence for conditioned or derived transfer of fear-potentiated eyeblink startle (a well-validated measure of fear in experimental psychopathology) through equivalence relations. Other physiological measures typically employed in anxiety research, like heart rate (e.g. Croft et al., 2004; Lundgren et al., 2004), remain unexplored in transfer-of-fear research.

It is noteworthy that almost none of the abovementioned studies analyzed the concurrent acquisition and transfer of conditioned fear (as physiological reactions) and avoidance. There is evidence that both fear respondents and avoidance behavior spread through stimulus equivalence classes and other relational networks, but little is known about their interaction in transfer-of-function experimental preparations when both types of responses are measured simultaneously. Some evidence in this regard was provided by a laboratory analogue study of the mechanisms of exposure therapy (Luciano et al., 2013). It analyzed the impact of direct and derived respondent fear extinction on avoidance behavior. Results showed stronger transfer of avoidance than of fear (measured through SCRs) to untrained class elements after direct avoidance training with other class elements, and show a decoupling of these two response classes, with avoidance behavior persisting in the absence of noticeable fear reactions (see also Luciano et al., 2014). Considering this, and the cumulating clinical and experimental evidences on the independence of avoidance behavior from Pavlovian fear reactions (e.g. Treanor &

Barry, 2017; see Smith et al., 2020, pp. 89-90 for a detailed discussion) it would be valuable to further address this understudied operant-respondent interaction in transfer-of-function research.

The present study attempts to advance the analysis of the transfer of fear and avoidance by using a contingency reversal design. The purpose of this contingency reversal is to re-test transfer effects upon a shift (CS+ elements become CS- and vice versa) in the function of only a subset of elements from each class. If such 'shifted' transfer is observed, it could be said that the arbitrary relations of equivalence between class members are more relevant for the expression of fear and avoidance than the direct history of avoidance conditioning of each particular element by itself. This procedure allows for the analysis of potential within-subject replication of transfer effects which has not been employed yet in studies on the transfer of avoidance. In order to further explore the transfer of conditioned fear and its interaction with avoidance behavior, the present study includes concurrent measurement of avoidance responses and of two physiological indices of fear: SCRs and changes in heart rate. Results are presented both individually and in terms of group-based statistical analysis.

METHOD

Participants

Participants were 24 healthy students from different courses at University of Almería, in Spain (70.83% female; age range: 18-30). All were recruited through campus flyers and in-class announcements. None of them had participated in psychological research before. Upon termination of the experimental session, all participants were debriefed and received a canteen voucher (exchangeable for breakfast or a snack) as a compensation for participation. All the procedures were reviewed and approved by the University of Almería Ethics Board of Research.

Setting, Apparatus, and Stimuli

The experiment was conducted in a laboratory consisting of two 4×3 m^2 adjacent rooms separated by a one-way mirror. The experimental room was dimly lit by a 40W bulb and equipped with a table, an armchair, a laptop computer with a 15-inch color screen, and several modules for the recording of skin conductance (SC) and heart rate (HR) responses (BIOPAC Instruments MP100SW, with GSR100C and ECG100A recording modules). The computer was programmed (with Microsoft VisualBasic® 6.0) to present visual stimuli and to coordinate the presentation of electric shocks, as well as to record participants' responses in some tasks. The

other room, used for observation of participants, contained a desktop computer that served to store and analyze the physiological response data.

SC was recorded through non-polarizable Ag/AgCl finger electrodes attached to the palmar side of the distal phalanx of the first and third finger of the participant's right hand. The electrodes had a round contact area (6mm diameter) inside a polyurethane mould, forming a cavity 1.6 mm deep that was filled with isotonic (0.5% NaCl) electrode gel. The system delivered a constant voltage (0.5V) current that allowed for the continuous measurement (DC) of SC level (i.e. constant voltage technique of exosomatic recording; see Dawson, Schell, & Filion, 1990), with a conversion rate of 5µS/V, and a low-pass band filter (1Hz). HR was recorded through disposable adhesive Ag/AgCl electrodes. These electrodes have a pre-gelled (7% NaCl) contact surface (11mm diameter) and an adhesive vinyl backing (35mm diameter). They were placed according to Einthoven's lead II (positive: left ankle; negative: right wrist; ground: right ankle). Electrodes were connected to an ECG100A amplifier with a gain of 5000. The amplifier avails of a peak detector circuit for the R-wave that allowed for online conversion of ECG to HR (in bpm). Analog-digital conversion was performed at a rate of 100 Hz and all physiological data were stored offline for later quantification and analysis.

An isolated square-wave stimulator (Lafayette 82415-IS) was used for the administration of electrocutaneous aversive stimulation. It delivered constant voltage electric shocks (300 ms duration) through two disposable adhesive round electrodes (identical to those used for HR measurement) attached to the inner surface of the participant's right arm. The laptop computer that presented the experimental tasks was connected to the physiological recorder and the stimulator through a custom-made parallel-port cable that delivered the electric pulses that triggered the presentation of shocks, as well as those that served as stimulus markers for the physiological records.

The visual stimuli used in the experiment were 15 black shapes framed in a square white background, presented on a general black background (see Figure 1). The size of the stimuli was 8×8 cm^2 for the equivalence class formation tasks (phases 1 and 8), and 10×10 cm^2 for the aversive conditioning/avoidance task (phases 2 to 7). For each participant, the shapes were randomly distributed into five-member sets by the computer. For procedural purposes, the stimuli in each group were designated with alphanumerical labels (e.g. A1, B2, C3), wherein letters identified each element in a group, while numbers identified the group to which the element belonged. Participants were unaware of these labels. Yellow arrows (8×2 cm^2) pointing either to the left, right, up or down, were used as contextual cues for avoidance responding (see below).

(Insert Figure 1 here)

Procedure

The experiment comprised eight different phases (see Figure 2). Phase 1 consisted of the formation (training and assessment) of two five-member equivalence classes. Phase 2 consisted of a Pavlovian differential aversive conditioning procedure, where two elements of Class 1 served as CS+ and two elements of Class 2 served as CS-. The UCS was a mild electric shock. Phase 3 consisted of avoidance training (participants could avoid the presentation of shock by pressing repeatedly on a keyboard key) with the same visual stimuli. Phase 4 was also an avoidance conditioning procedure, with the remaining elements of Class 1 as CS+/S^D and the remaining elements of Class 2 as CS-/S^Δ. The first block of trials in this phase served as the first transfer test. Phase 5 consisted of a Pavlovian aversive conditioning procedure again, but in this case conditioning contingencies were reversed (i.e., two members of Class 2 served as CS+ and two members of Class 1 served as CS-). Phase 6 consisted of avoidance conditioning with these stimuli. Phase 7 consisted of avoidance conditioning with the remaining two elements of each class, so that Class 2 elements served as CS+/S^D and Class 1 elements served as CS-/S^Δ (2^{nd} transfer test). Finally, Phase 8 was a re-test of the derived symmetry and equivalence relations established during Phase 1. All phases were conducted in one experimental session that lasted between 60 and 120 minutes. Participants were tested individually.

(Insert Figure 2 here)

Upon reporting to the laboratory, participants received an explanation of the general procedures that would follow. The experimenter explained that participation entailed receiving the administration of several shocks of moderate intensity, the level of which would be selected by the participants themselves so that the sensation produced by the shock was definitely unpleasant, but not painful. He placed special emphasis on the fact that participation was absolutely voluntary, and that participants were free to abandon the experiment at will. Then, participants read and signed a statement of informed consent and they were conducted to the experimental room and began the session.

Phase 1: Formation of equivalence classes. Participants underwent training in eight different conditional discriminations (A1B1, A1C1, A1D1, A1E1, A2B2, A2C2, A2D2, A2E2) through a simultaneous matching-to-sample procedure (Sidman & Tailby, 1982) with three comparisons. After the establishment of these eight relations, they underwent the assessment of derived symmetry and transitivity relations, in order to determine whether two equivalence classes had been established (Class 1: A1-B1-C1-D1-E1; Class 2: A2-B2-C2-D2-E2). Stimuli

from the third set of abstract shapes (A3, B3, C3, D3, E3) served as incorrect comparisons in conditional discrimination training and testing. No specific relations amongst them were trained or tested.

Both during training and test trials, a sample (e.g. A1) appeared in the center of the upper third of the screen. One s later, three comparisons (e.g. B1, B2 and B3) appeared in line in the horizontal lower third of the screen, one of them in the middle, one on the right side, and the other one on the left side. In each trial, the comparisons were randomly assigned to each of the three positions in the lower third of the screen. Participants had to select one of the three comparisons by clicking on it with the mouse. After this selection, all the stimuli were removed from the screen. During training trials, selection responses were followed by written feedback on the screen. Selection of the correct comparison was followed by the presentation of the word "CORRECT" in capital letters and white color, centered on the screen. Incorrect responses were followed by the word "WRONG" in the same format. Feedback remained on the screen for two s, after which the screen went blank for 1.5 s (i.e. the ITI). During test trials, responses were just followed by the ITI, without any feedback. The following instructions were presented on screen before the task started:

"In this part of the experiment you will see four shapes on the screen in each trial, one in the middle of the top of the screen, and the other three on the bottom: one on the right, one on the left, and one in the middle. The task consists of selecting the correct shape out of those three in the lower part of the screen, by clicking on it with the mouse. During the first part of the task, the computer will give you feedback on each response, indicating whether it is correct or wrong. Later in the task, the computer will not give feedback about your responses. However, there will be correct and incorrect responses, and you have to get as many correct responses as possible.

At first, the task will be easy and you may even notice that it is not necessary to pay a lot of attention. However, task difficulty will increase gradually, and in order to select the correct shapes during the last part of the task, you must have previously performed the task correctly during the initial parts. So, it is important that you pay a lot of attention from the beginning of the task. Everything you learn during this part of the experiment will be important for later phases. If you have any doubts, please ask the experimenter. Click here to start."

(Insert Table 1 here)

The eight directly trained relations were presented in eight-trial blocks (one trial per relation). Each trial consisted of the presentation of the sample and its corresponding group of comparisons (see Table 1). Within each block, the presentation order of trials was randomized.

Blocks were presented continuously until the participant reached a performance criterion of 61 correct responses out of eight consecutive complete blocks (64 trials). After reaching the training criterion, participants underwent a test of symmetry relations. This stage started with the presentation of the following written instructions on the computer screen:

"Now you will keep performing the task. This time the computer will not give you any feedback about your responses, but there are still correct and incorrect responses. You have to get as many correct responses as possible. Click here to continue."

The following eight relations were tested: B1A1, B2A2, C1A1, C2A2, D1A1, D2A2, E1A1, and E2A2. They were presented in eight-trial blocks (one trial per relation) with trials presented in random order for each block. Symmetry blocks were presented continuously until participants reached the same performance criterion established during training (61 correct responses out of eight consecutive blocks).

Once they reached criterion, participants underwent a final combined test of symmetry and transitivity relations. This stage started with the presentation of the same instructions that preceded the symmetry tests. In addition to the eight symmetry relations, the following 24 relations were tested: B1C1, B2C2, B1D1, B2D2, B1E1, B2E2, C1D1, C2D2, C1E1, C2E2, C1B1, C2B2, D1E1, D2E2, D1C1, D2C2, D1B1, D2B2, E1B1, E2B2, E1C1, E2C2, E1D1, and E2D2 (see Table 1). They were presented in 32-trial blocks, one trial per relation. Within each block, trials were presented in random order. These blocks were presented continuously until the participant reached the criterion of 153 correct responses out of five consecutive blocks (i.e. 160 consecutive trials), with a maximum of two errors for each particular relation. After reaching criterion, participants passed to the next phase of the experiment. Participants failing to reach performance criteria for conditional discrimination training or any of the tests after 500 consecutive trials were stopped and scheduled for a second experimental session the next day.

Phase 2: Aversive conditioning. Although they will be described separately, Phases 2 to 7 were presented consecutively, as part of the same experimental task, without breaks or stops between them. Prior to the beginning of the task, the experimenter cleaned with ethanol (96%) the relevant skin areas and then attached the stimulation and recording electrodes on the appropriate sites (as seen in the *Setting, Apparatus, and Stimuli* section). After making sure that the physiological responses were being properly recorded, the experimenter requested the participant to breathe deeply and checked if this produced a visible increase in skin conductance level, which happened in all cases. Then a shock work-up procedure started with a 20 V shock. The experimenter gradually increased shock voltage in 20 V steps, until the participant indicated that the stimulation was unpleasant (at this point the voltage of the last

shock was selected) or that it was painful. In the latter case, the experimenter decreased shock voltage (in 10 V steps) until the participant reported the shock to be unpleasant but not painful. The minimum voltage selected by any participant was 40 V and the maximum was 100 V. After shock voltage selection, the following instructions were presented on the screen:

"During this phase of the experiment you will be presented with some shapes on the screen, one at a time. It is important that you pay attention to the screen and to the shapes appearing on it. Some of those shapes will be followed by a shock of the same magnitude you have just selected (some other shapes will not). Initially the computer screen will remain blank for a few minutes, just in order to have your physiological activity at a steady level. After this interval, shapes will start to appear on the screen. In some occasions, a yellow arrow (pointing either to the left, right, up, or down) will appear above the shape on screen. On those occasions, if you think that the shape on screen predicts the presentation of shock, you will have the chance to cancel the upcoming shock by quickly and repeatedly pressing the cursor key that matches the arrow on screen. It is important that you wait for the presentation of the arrow on screen in order to press the correct key (otherwise, you will not know which key you have to press!). If you press any key before the arrow appears, the keyboard will turn off and you won't have the chance to avoid the upcoming shock. It is important that you remember that arrows will appear above the shapes only in some occasions. If no arrow appears, then you cannot do anything to avoid shock. Also, it is important that you understand that an arrow doesn't mean that shock is coming. It is the shape that will indicate whether shock is coming or not. Arrows will appear above any type of shape, and they only indicate the correct key you can press in case you think shock is coming. This is important because you only have a limited number of avoidance responses available. If you spend your avoidance responses with shapes that do not predict shock you might end up without any responses left for when you need them.

During this phase you don't have to use the mouse. All you have to do is pay attention to the screen, and remain seated and quiet (except for pressing the cursor keys when necessary). It is important that you try not to move, cough, sneeze, laugh, etc., as all of these actions can interfere with the physiological recordings. Please address the experimenter in order to comment on the instructions."

After that, the experimenter clarified any doubts the participant might have. Then he left the room and the conditioning/avoidance task began with a five-min baseline period during which the screen remained blank.

Participants underwent a differential delay conditioning procedure, where B1 and C1 served as CS+ (paired with shock) and B2 and C2 served as CS- (no shock). All CSs had a

fixed duration of eight s and they were individually presented, centered on the screen. The presentation of B1 and C1 was always followed by the presentation of a 300 ms electric shock (UCS) simultaneous to CS offset. B2 and C2 were never followed by shock. The ITI had a randomly assigned variable duration (25-35 s). Two four-trial blocks (one trial per stimulus, in random order) were presented. Since avoidance responding was not trained in this phase, no arrows were presented.

Phase 3: Avoidance training. This phase consisted of avoidance training with the same stimuli that had served as CSs in Phase 2. B1 and C1 served as discriminative stimuli (S^D) for avoidance responses while B2 and C2 served as S^Δ. Training proceeded as in the previous phase, in four-trial blocks (one per stimulus in random order), with identical temporal parameters for CS duration and ITI. In each trial, a yellow arrow (pointing either to the left, right, up, or down) was flashed above the CS for the last three s of the CS-duration interval. The arrow served as a cue that signaled the opportunity to produce avoidance responses (consisting of pressing the cursor key that matched the arrow on the screen). Five (or more) keypresses during the three s that the arrow cue was present cancelled the presentation of shock (but not the CS on screen). When the CS duration interval was over, both the CS and the avoidance cue disappeared simultaneously. If the participant failed to produce at least five keypresses, B1 and C1 were followed by shock (like in Phase 2). B2 and C2 were never followed by shock (regardless of the participant's responding). Participants were trained to criterion until they produced two consecutive correct four-trial blocks. A block was considered correct when participants produced avoidance responses with B1 and C1, but not with B2 or C2. If a participant did not reach this criterion after eight consecutive blocks s/he was discarded from further participation. There was no limit to the number of avoidance responses participants could produce, despite participant instructions stating otherwise. This bogus instruction was included in order to prevent generalized avoidance to all stimuli (either paired with shock or not).

Phase 4: Transfer test 1. This phase was almost identical to Phase 3, with the only exception that the elements presented were D1 and E1 (as CS+/S^D) and D2 and E2 (as CS-/S^Δ). Participants were trained to criterion until they produced two consecutive correct four-trial blocks. A block was considered correct when participants produced avoidance responses with D1 and E1, but not with D2 or E2. The first block of trials in this phase served as a transfer test. If participants produced avoidance responses with the first presentation of both D1 and E1, but not of D2 or E2, then a transfer-of-function effect was obtained. It is important to note that the aversive conditioning/avoidance contingencies were maintained during this phase (i.e., the

transfer test was not presented in extinction), so that all four elements from each class would be directly trained before the contingency reversal (i.e., if participants failed to produce avoidance responses with D1 or E1, they were shocked). Since this was a delay conditioning procedure and all the pertinent responses were recorded before the time of UCS presentation (i.e. they were anticipatory responses), the first time any stimulus was presented constituted a valid transfer test, for it lacked a history of direct conditioning or avoidance training (for a more detailed explanation, see Valverde et al., 2009, p. 96).

Phase 5: Aversive conditioning (contingency reversal). This phase was almost identical to Phase 2, with the only difference that now the stimuli that served as CS+ (i.e., that were paired with shock) were two elements of Class 2 (B2 and D2), while two elements from Class 1 (B1 and D1) served as CS- (i.e. were not paired with shock). That is, there was a reversal of the aversive conditioning contingencies with two elements from each class. This reversal was performed with the B and D elements of each class (rather than the B and C elements) in order to avail of a subsequent reversed-transfer test (see Phase 7, below) with at least one stimulus (C1) that had been directly paired with shock (D1 or E1 might have been paired or not, depending on whether the participant avoided any of them on the first transfer test).

Phase 6: Avoidance training (contingency reversal). This phase was almost identical to Phase 3, with the only difference that it applied the same contingency reversal as in Phase 5. That is, B2 and D2 served as CS+/S^D, while B1 and D1 served as CS-/S^Δ.

Phase 7. Transfer test 2 (contingency reversal). This last phase of the aversive conditioning/avoidance task was almost identical to Phase 6, with the only difference that the stimuli presented were the remaining elements of each class (maintaining the aforementioned contingency reversal). Accordingly, C2 and E2 served as CS+/S^D (i.e., predicted the presentation of shock), while C1 and E1 served as CS-/S^Δ (no shock). As previously mentioned for Phase 4, the first block of trials in this phase served as a transfer test, given that it was the first presentation of C1, E1, C2, and E2 according to the reversed contingency arrangement. The first time each of these stimuli was presented, it had a direct history of aversive conditioning or avoidance responding that was just the opposite of the reversed contingency arrangement. So far, C1 and E1 had the set occasion for avoidance responding, while C2 and E2 had not.

Phase 8: Re-test of equivalence classes. Participants underwent a new assessment of the previously established equivalence relations. The procedures were identical to those in the combined symmetry/transitivity test in Phase 1, with the difference that instead of running the task continuously until the achievement of a performance criterion, the task consisted of five

32-trial blocks (one trial per each symmetry and transitivity relation per block, see Table 1), which amounted a total of 160 trials.

Response quantification and data analysis

Two indices of autonomic arousal were measured: skin conductance responses (SCRs) and heart rate responses (HRRs). Both of them were measured as anticipatory responses, i.e., the analyzed time interval was always prior to CS offset/UCS onset. Specifically, they were quantified only for the first 5 s of the 8 s CS-duration interval in order to prevent recording of potential somatic interference from avoidance responding during the last three seconds of the CS-duration interval. All physiological records were visually inspected for artefacts or interferences. SCRs were quantified as the largest increase in skin conductance (measured in μSiemens [μS]) from the point of response onset, whenever this point took place at least 0.5 s after CS onset. This is consistent with the so-called first interval responses (FIRs) in the SCR conditioning literature (see Öhman et al., 2000; Prokasy & Kumpfer, 1973). Decreases in skin conductance during the measured interval were quantified as zero and included in all analyses. Square roots of all SCR data were calculated in order to normalize data distributions before statistical analyses.

HRRs were quantified as follows: HR variation (in beats-per-minute, bpm) during CS presentation was calculated on a second by second basis against a baseline consisting of the average HR for the two second interval immediately prior to CS onset with custom-made software that adapted an original program by Redondo (2003). This software provides on the basis of the records' raw data (100 data points per s) the average HR variation against baseline for each s in the analyzed interval (rendering 5 HR variation data points per analyzed interval, in this case). In a delay conditioning paradigm like the one employed in this study there is typically an acceleration of HR around seconds 4-5 after CS onset (see Marcos & Redondo, 2001; Neumann & Waters, 2006; Obrist et al., 1969; Redondo, 2003; Redondo & Marcos, 2001). Since this response component would be free from potential somatic interferences from avoidance responding, we quantified HRRs for each trial and participant as the average HR variation against baseline for seconds 4 and 5 after CS onset.

As already mentioned, a minimum of five keypresses had to be produced in order to avoid the presentation of shock. The total keypresses in each trial was recorded and included in statistical analyses.

Results regarding aversive conditioning/avoidance training and transfer tests are presented both individually and at a group level (see below). For each of the three measures

(avoidance responses, SCRs, and acceleratory HR responses), two separate repeated measures 4×2 ANOVAS (Trial × Stimulus class, both factors within-subject) were performed (one for phases 3 and 4, before the contingency reversal; another for phases 6 and 7, after the contingency reversal). For the first ANOVA, the analysis was performed for the dataset comprising the last trial of each stimulus in Phase 3 (last presentation of each directly conditioned stimulus during avoidance training) and the first trial of each stimulus in Phase 4 (1^{st} transfer test). For the second ANOVA, the dataset comprised the last trial of each stimulus in Phase 6 (last presentation of each directly conditioned stimulus after the contingency reversal) and the first trial of each stimulus in Phase 7 (2^{nd} transfer test). Where Mauchly's test revealed that sphericity was not met, the Greenhouse-Geisser correction was applied (original degrees of freedom are reported, accompanied by ε where necessary). Where necessary, planned comparisons (related-samples *t* tests) were performed after the ANOVAS. The alpha-level was set at 0.05 for all analyses.

RESULTS

Formation of equivalence classes. A total of 22 out of 24 participants (91.67%) completed the formation of equivalence classes (see Table 2). Seventeen participants reached training and test performance criteria during their first exposure to the experimental procedures. Seven participants (P1, P4, P10, P12, P19, P20, and P24) failed to achieve training or test criteria after more than 500 consecutive trials and were scheduled for retraining the next day. Five of them (P1, P10, P12, P20, and P24) completed the formation of equivalence classes during this second exposure. P4 and P19 did not return for retraining and were discarded from further participation. Considering their last exposure to the training and testing procedure, participants required a mean of 124.73 (SD=52.99) trials to achieve criterion in conditional discrimination training, a mean of 72 (SD=37.5) test trials (a little more than one test cycle) to reach criterion in symmetry tests, and a mean of 160 trials (one test cycle) for the combined symmetry and equivalence test.

(Insert Table 2 here)

Avoidance responding. Twenty-two participants started the conditioning/avoidance task (phases 2 to 7). P23 did not reach the avoidance-training criterion in Phase 3 after eight consecutive blocks, while P20 could not finish the task due to a failure in the power supply (all of her data were lost). They are not included in the analyses.

Table 3 presents, for each participant, avoidance responses to the stimuli in each class during phases 3 (last trial-block), 4 (first trial-block), 6 (last trial-block), and 7 (first trial-block). Avoidance responding was trained to criterion in each of these phases (up to two consecutive

correct blocks). Accordingly, not all participants underwent the same number of trials in each phase. In Phase 3 all participants but three reached the avoidance training criterion in eight trials (with no mistakes). P17 and P9 needed 20 trials, while P1 needed 12 trials. In Phase 6, after the contingency reversal, all participants reached criterion in eight trials but P9, who needed 12 trials. Shaded rows in the table indicate that the participant achieved the transfer criterion for that specific transfer test (phases 4 and 7). Ten out of 20 participants (50%) showed a transfer effect in the first test (i.e., they showed avoidance responding to D1 and E1, but not to D2 and E2). Nine of these 10 showed a transfer effect again in the second test, after the contingency reversal (i.e., they keypressed in the presence of C2 and E2, which had a direct history of serving as S^{Δ} for avoidance responding, and not in the presence of C1 and E1, which had a direct history as S^{D} for avoidance responding). Besides, seven participants that had not shown transfer effects in the first test did so in the second test, after the contingency reversal. This renders a total of 16/20 (80%) showing transfer of avoidance-evoking functions in the second transfer test. These results are indicative of a strong transfer effect after the reversal.

(Insert Table 3 here)

The upper graph in Figure 3 shows avoidance results collapsed across participants. (Given that in phases 3, 4, 6 and 7 training was performed to criterion--hence different participants underwent a different number of trials--all graphs in Figure 3 only include the initial and the last block of trials for each of these phases). The graph shows a clear difference between stimulus classes, with avoidance responding to the elements of Class 1 (and not to the elements of Class 2) in phases 3 and 4, and the opposite pattern of responding (avoidance responses to Class 2 stimuli, and not to Class 1 stimuli) in phases 5 and 6 (after the contingency reversal). These results were confirmed by statistical analyses. For the first transfer test, the ANOVA shows a main effect for stimulus class, $F(1, 19)= 162.467$, $p< .001$ ($\eta^2_p= .895$). It also shows a main effect for trial, $F(3, 57; \varepsilon= .666)= 8.603$, $p= .001$ ($\eta^2_p= .312$) and a significant interaction, $F(3, 57; \varepsilon= .657)= 8.638$ ($\eta^2_p= .313$). Planned comparisons were performed in order to ascertain that the difference in avoidance responding between stimulus classes was maintained across trials. For each trial (trials 7, 8, 9, and 10 in the graph) we compared avoidance responses to the Class 1 stimulus and to the Class 2 stimulus. All related-samples *t* tests were significant (all *p*s< .001), with the first trial in the transfer test showing the smallest effect, $t(19) = 4.414$ ($d_z= .987$). For the second transfer test (after the reversal) the ANOVA shows a clearly significant effect for stimulus class, $F(1, 19)= 302.414$, $p<.001$ ($\eta^2_p= .941$), but not for trial, nor an interaction (both *p*s=.185). This indicates that after the reversal, avoidance responses were produced to Class 2 stimuli and not to Class 1 stimuli, both during the avoidance training and the transfer test trials.

(Insert Figure 3 here)

Skin conductance responses. Table 4 presents, for each participant, SCRs (in μS) to the stimuli in each class during phases 3, 4, 6, and 7. The criterion to determine that there was differential fear conditioning in Phase 3 was larger SCRs to both B1 and C1 than to B2 and C2 in the last block of trials. In Phase 4 any participant was deemed to achieve transfer if they showed larger SCRs to both D1 and E1 than to D2 and E2 in the first block of trials. Likewise, after the reversal the criterion for conditioning (Phase 6) was larger SCRs to B2 and D2 than to B1 and D1, whereas the transfer (Phase 7) criterion was larger SCRs to C2 and E2 than to C1 and E1. Shaded rows highlight participants meeting criteria for the different phases. Thirteen participants (65%) showed differential fear conditioning in Phase 3. Three of those (P7, P5, and P2) also showed transfer of respondent elicitation with SCRs. Additionally, two participants (P24 and P12) met the transfer criterion without previously showing differential conditioning (amounting to 25% of the sample meeting criterion for transfer in the first test). After the reversal, only one participant showed both conditioning and transfer with SCRs (P17).

The middle graph in Figure 3 presents square-roots of SCRs collapsed across participants and class members. Unlike the individual data, the group graph shows a clear differential pattern of SCR responding between stimulus classes, with higher SCRs to the elements of Class 1 in both phases 3 and 4. The ANOVA for phases 3 and 4 shows a significant main effect for stimulus class, $F(1, 19)= 40.709$, $p< .001$ ($\eta^2_p= .682$), but no significant trial effect ($F< 1$) or interaction [$F(3, 57; \varepsilon= .732)= 2.107$, $p= .130$]. This is indicative of larger SCRs to Class 1 stimuli than to Class 2 stimuli both during the last trials of avoidance training and during the first transfer test. The ANOVA for phases 6 and 7 (after the contingency reversal) shows no significant main effects or interaction (all ps$> .150$). This is indicative that there was no differential pattern of arousal during the last trials of the second avoidance training phase or in the second transfer test.

Heart rate responses. Nineteen participants produced valid data for this measure. One participant (P10) completed the task but the electrodes for cardiac activity fell off during her performance and no HR measures are available for her. Table 5 presents, for each participant, HRRs (bpm) to the stimuli in each class during phases 3, 4, 6, and 7. The same criteria for conditioning and transfer were used as with SCRs (larger acceleratory HRRs for Class 1 stimuli in Phases 3 and 4, and for Class 2 in Phases 6 and 7). Shaded rows highlight participants meeting criteria for the different phases. Only four participants (21.05%) showed fear conditioning with this measure in Phase 3, two of which (P21 and P11) also met the individual criterion for transfer. Additionally, six participants that did not show fear conditioning met the criterion for transfer (a total 8/19, 42% of the sample). After the contingency reversal, two participants (P15 and P22)

met the conditioning criterion but none of them showed transfer, and an additional two participants (P6 and P17) met the transfer criterion in Phase 7 without having previously met the conditioning criterion in Phase 6.

The lower graph in Figure 3 presents data for HRRs collapsed across participants for the same trials as with the other measures. This graph shows much more variability and only for the last trials of avoidance training (trials 7 and 8) and the first transfer test trials (trials 9 and 10) appears a differential pattern of responding, with larger HRRs to Class 1 than to Class 2 stimuli. For phases 3 and 4 (before the contingency reversal), the ANOVA shows a main significant effect for stimulus class, $F(1, 19)= 14.667$, $p= .001$ ($\eta^2_p= .449$), but no trial effect or interaction (both *p*s> .325), which is indicative of larger HRRs both during the last avoidance training trials and the first transfer test trials. No significant main or interaction effects were obtained for phases 6 and 7 (after the reversal), with the interaction being the one that approached significance the most, $F(3, 54; \varepsilon= .826)= 2.340$, $p= .097$. As with SCRs, there was no differential pattern of HR changes either during the second avoidance training phase or in the second transfer test.

Re-test of equivalence relations. All participants responded correctly during the combined symmetry and transitivity test, with at least 97.5% accuracy (see Table 2).

DISCUSSION

These results reveal that when Pavlovian fear responses and avoidance are measured simultaneously, only avoidance shows an orderly pattern of differential responding and transfer that is evident at a group level and that replicates clearly both within and between participants. To the contrary, although the group-based analyses are indicative of differential conditioning and transfer of fear with electrodermal and cardiovascular measures (before the contingency reversal), the between-subject replication evidence with these measures is weaker. Only a very reduced proportion of participants met the individual transfer criterion with SCRs, despite having previously shown differential SCR conditioning. For HRRs, the proportion of participants meeting the individual criterion for transfer in the first test was larger, however most of them had not previously shown differential conditioning. This reflects large individual variability for both physiological measures that contrasts with the consistency of results for avoidance.

For avoidance, half of the sample met criterion in the first transfer test and 80% of the sample met the transfer criterion in the second test. This second, stronger transfer effect involves an indirect alteration of functions for stimuli that already had some experience controlling an incompatible response. In brief, although C1 and E1 had a direct history as $CS+/S^D$ for avoidance before the reversal, on their first presentation in Phase 7 (second transfer test) they did not evoke

any avoidance responses. Likewise, C2 and E2, with a direct history as CS-/S^{Δ}, did evoke avoidance responses on their first presentation in Phase 7. These results indicate that derived equivalence relations were a more relevant source of control over avoidance responding than each particular stimulus' direct history of aversive conditioning or avoidance training. However, derived equivalence established through conditional discrimination training and testing seems insufficient to explain the stronger transfer effect in the second test, for these relations were already established for the first transfer test. One obvious candidate to explain this 'increased' transfer effect is the commonly trained avoidance/non avoidance functions for four elements in each equivalence class during the aversive conditioning/avoidance task. This might have strengthened the existing functional equivalence amongst class elements (see Goldiamond, 1966; Markham & Markham, 2002; Sidman et al., 1989) so that a direct contingency reversal with only a subset of elements transformed the function of elements not yet exposed to the new contingency arrangement. [1] In the terms of Relational Frame Theory (RFT: Hayes, Barnes-Holmes, & Roche, 2001), participants received both C_{rel} training (training that specifies the type of relation between the stimuli, i.e. equivalence class formation) and C_{func} training (training that specifies the relevant behavioral function of the stimuli in the experimental task, i.e. commonly trained aversive/non-aversive functions).

A procedural feature of the study might also play a part in explaining these results. Participants received a bogus instruction to not 'waste' their avoidance responses in order to prevent overgeneralized avoidance responding (both to CS+ and CS- elements). This might have led some participants to rely on their direct experience with each stimulus in the aversive conditioning task, so that upon encountering a CS+ related element for the first time (lacking direct experience with it) they were unlikely to 'gamble' their 'limited' avoidance responses on it. Upon being shocked with it too, participants would then avoid any CS+ related element on the next possible occasion. This is a potential limitation that should be addressed in future research.

The findings resulting from statistical analyses of avoidance were consistent with those from the individual analysis, with significantly more avoidance responses for Class 1 elements than for Class 2 elements in the first test, and more responses to Class 2 elements than to Class 1 elements in the second test. In addition, statistical tests showed smaller differences between stimulus classes in the first transfer test than in the second.

[1] It is worth mentioning that the results of the second transfer test can not be attributed to functional equivalence resulting exclusively from commonly trained avoidance/non avoidance functions. A control experiment (not included in the present report due to space limitations) conducted with eight participants who were not taught the equivalence classes and underwent only phases 2 to 7 (the conditioning-avoidance task) did not show comparable results, with no participants meeting the transfer criterion in the first test, and only two (25%) meeting it in the second test. These data are available from the first author upon request.

The picture is different for physiological measures. For SCRs, only a quarter of the sample met the transfer criterion in the first test (some of them not having met the differential conditioning criterion before) and only one participant met criteria for differential conditioning and transfer in the second test. A substantial number of participants did not produce any SCRs during most trials, particularly after the contingency reversal. With HRRs, a larger fraction (42%) met the transfer criterion, but most of them had not met the differential conditioning criterion before. The proportion of participants meeting differential conditioning and transfer criteria is largely reduced after the contingency reversal. These results reflect the inherently large variability of psychophysiological measures, which is subject to a host of uncontrollable variables (fleeting thoughts, body posture, changes in respiration rhythm, fatigue, habituation, etc.). It is worth noting, though, that prior research that used a very similar design without avoidance training (Valverde et al., 2009), found clear evidence (across individual participants) of differential conditioning and transfer of respondent elicitation with SCRs in the first test (and some degree of conditioning and transfer in the second). Since the critical training and transfer trials in the present study were all avoidance conditioning trials, it seems that the availability of avoidance had a substantial impact on respondent functions.

It has been argued that in signaled avoidance procedures, both the signal and the avoidance response might function like safety cues that prevent fear reactions (Dinsmoor, 2001), and there is growing evidence from human research on directly trained avoidance that, in the presence of cues signaling the opportunity to avoid a CS+, conditioned SCRs will gradually decrease as participants learn that avoidance responses effectively cancel the UCS (e.g. Lovibond et al., 2013; Vervliet & Indekeu, 2015). With a transfer-of-function preparation, Luciano et al. (2013, 2014) observed stronger transfer effects with avoidance measures than with SCRs, and sustained avoidance responding to several class elements in the absence of noticeable arousal. Unlike these studies, wherein SCRs were measured during a time interval when participants were exposed to cues signaling the opportunity to avoid, in the present study the avoidance cue (the arrow) was presented only after the measurement interval for SCRs and HRRs had elapsed. Accordingly, our measures of conditioned fear were obtained before the presentation of an explicit avoidance cue or the emission of avoidance behavior that might function like safety cues. It is possible, however, that the very structure of the aversive conditioning/avoidance task, with consecutive (and perhaps predictable) phases of Pavlovian conditioning, avoidance training, and transfer (with no interspersed Pavlovian conditioning trials in the latter two) somehow sufficed to signal periods of safety from shock (upon the correct emission of avoidance responses), so that the presentation of a CS+ or a CS+ related stimulus in this temporal context failed to elicit fear

reactions. It is also possible that habituation of conditioned fear responses played a part, because the aversive conditioning/avoidance task was rather long, comprising a minimum of 48 trials (at least 24 of them involving the actual or potential presentation of shock). In any case, our results, like those from the abovementioned studies (Lovibond et al., 2013; Luciano et al., 2013, 2014; Vervliet & Indekeu, 2015) and from prior research on animal and human conditioning (e.g. Mineka, 1979), suggest a functional independence between anxiety and avoidance that challenges the classical two-factor view that conditioned fear is necessary to motivate avoidance behavior (Mowrer, 1939). Research findings on the decoupling between conditioned fear and avoidance highlight the importance of studying the multiple sources of stimulus control over these two response classes for a fuller behavioral conceptualization of each.

Unlike findings with avoidance, there is a clear discrepancy between the conclusions based on individual analysis and those based on group statistical analyses for both physiological measures. On average, participants show larger physiological reactions to Class 1 elements than to Class 2 elements both during the last trials of avoidance training and the first transfer test trials (but not after the contingency reversal). These results are similar to published results deemed to demonstrate a transfer-of-function (symbolic generalization) effect with SCRs (Vervoort et al., 2014). If these statistical analyses were the only metric for the consideration of our results it could be argued that they constitute the first evidence of transfer of fear with a cardiovascular measure, as well as a replication of existing evidence on the transfer of fear with electrodermal activity. However, upon consideration of individual data it seems fair to question the extent to which the results of statistical analysis are representative of the actual performance of individual participants. It can be argued that the discrepancy between the individual and the group-based, statistical analyses is due to a more stringent criterion for the former. While the individual criterion for any transfer test is larger responses to both CS+ related stimuli than to any CS- related stimuli, the statistical analysis collapses data across class members, picking up the fact that most participants show larger averaged physiological responses to Class 1 members than to Class 2 members on the first transfer test. Had we chosen an individual criterion for conditioning and transfer that capitalized on this fact, the proportion of participants meeting it would have been substantially larger for both physiological measures. However, it should be noted that such criterion could be easily achieved by chance (there is roughly a 50% probability that average responses to one class will be higher than responses to the other). It is our view that the selected criterion is more appropriate as an index of transfer on an individual basis, and more consistent with prior research in the field (e.g., Dougher et al., 1994; Valverde et al., 2009).

Findings like those in the present study highlight the relevance of Sidman's classical behavior-analytic approach to experimental design and methodology (Sidman, 1960), a still valid warning that the statistical aggregation of individual subjects risks obscuring individual variability and may hinder adequate experimental control. A much more recent treatment of psychophysiological measures in fear conditioning (Ney et al., 2018) alerts against the problems of current standard inferential statistical approaches. In providing the individual data of participants for the critical trials, at least we provide a context for the interpretation of average-based graphical representations and statistical analyses. Psychophysiological measures of conditioned fear produce noisy data with large individual variability, and the study of transfer of fear with these measures needs further exploration that adequately addresses the challenges inherent to them. Experimental analyses are now needed to identify the contextual variables that may produce more robust individual-participant transformation effects using physiological and indeed other measures. For instance, recent findings across two studies (Leech et al., 2018, 2020) where a latency-based measure (the implicit relational assessment procedure: IRAP, Barnes-Holmes et al., 2010) was used to train and to test for the transformation of fear responses using pictures of spiders as aversive stimuli, suggest that increasing the level of exposure to opportunities to derive combinatorial entailment relations may facilitate the subsequent transformation of fear functions in accordance with such relations. Perhaps exposing participants to multiple equivalence tests and/or using different equivalence testing contexts, would increase the likelihood of obtaining relatively reliable derived transfer test performances at both the group and individual level? Although this is speculative at this point, future research could certainly pursue this line of inquiry.

The study of transfer and transformation of fear and avoidance is key for a solid behavioral conceptualization of human anxiety and its clinical manifestations. We hope that the current findings will contribute to this growing area of research and to experimental psychopathology research informed by behavior analysis.

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Figure 1.

Abstract shapes used as arbitrary stimuli for the formation of equivalence classes.

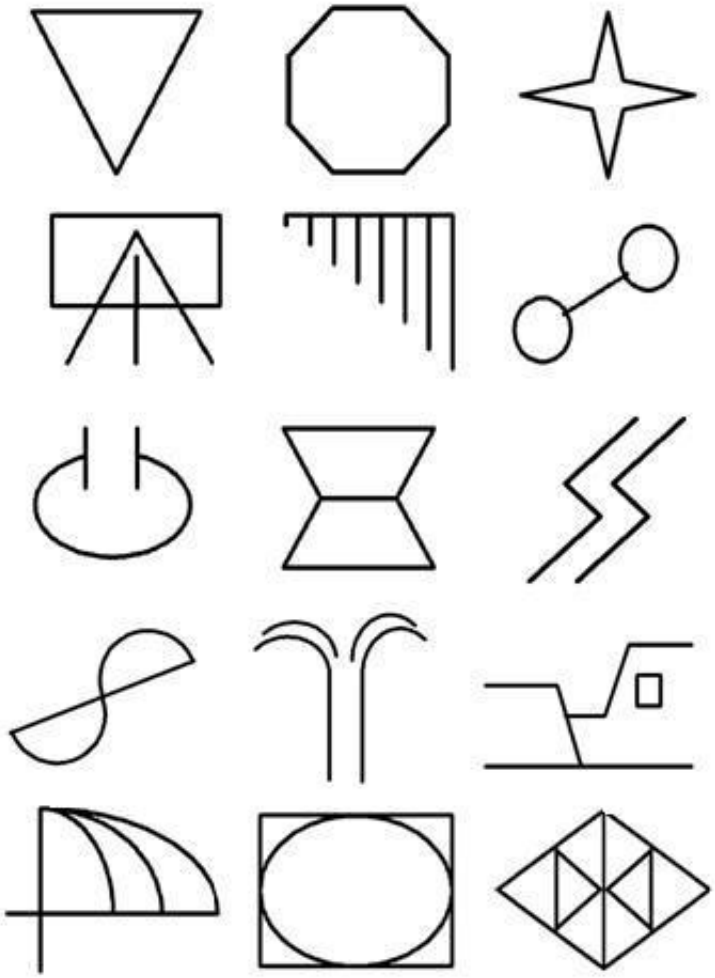


Figure 2.
Schematic depiction of the phases in the study.

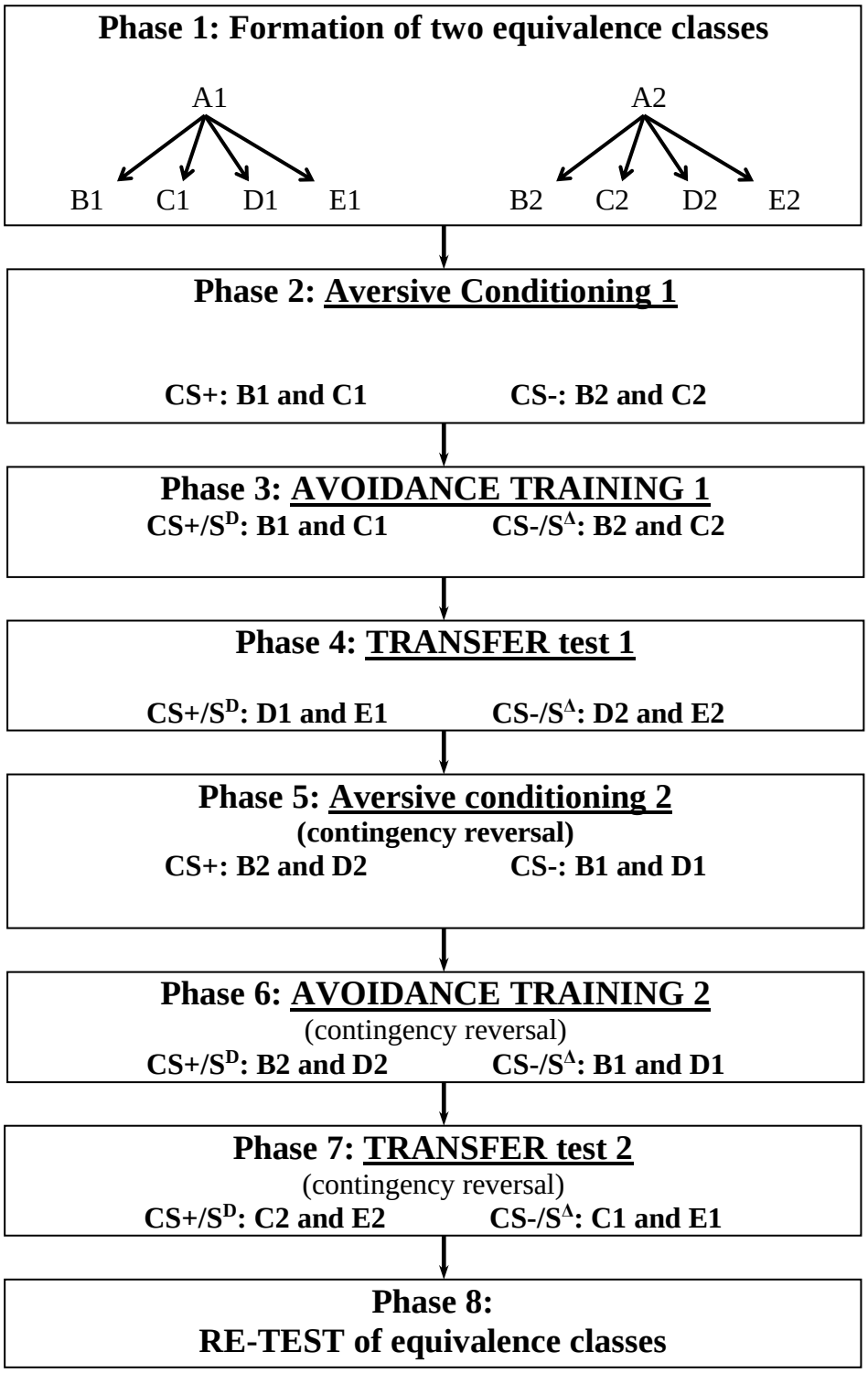
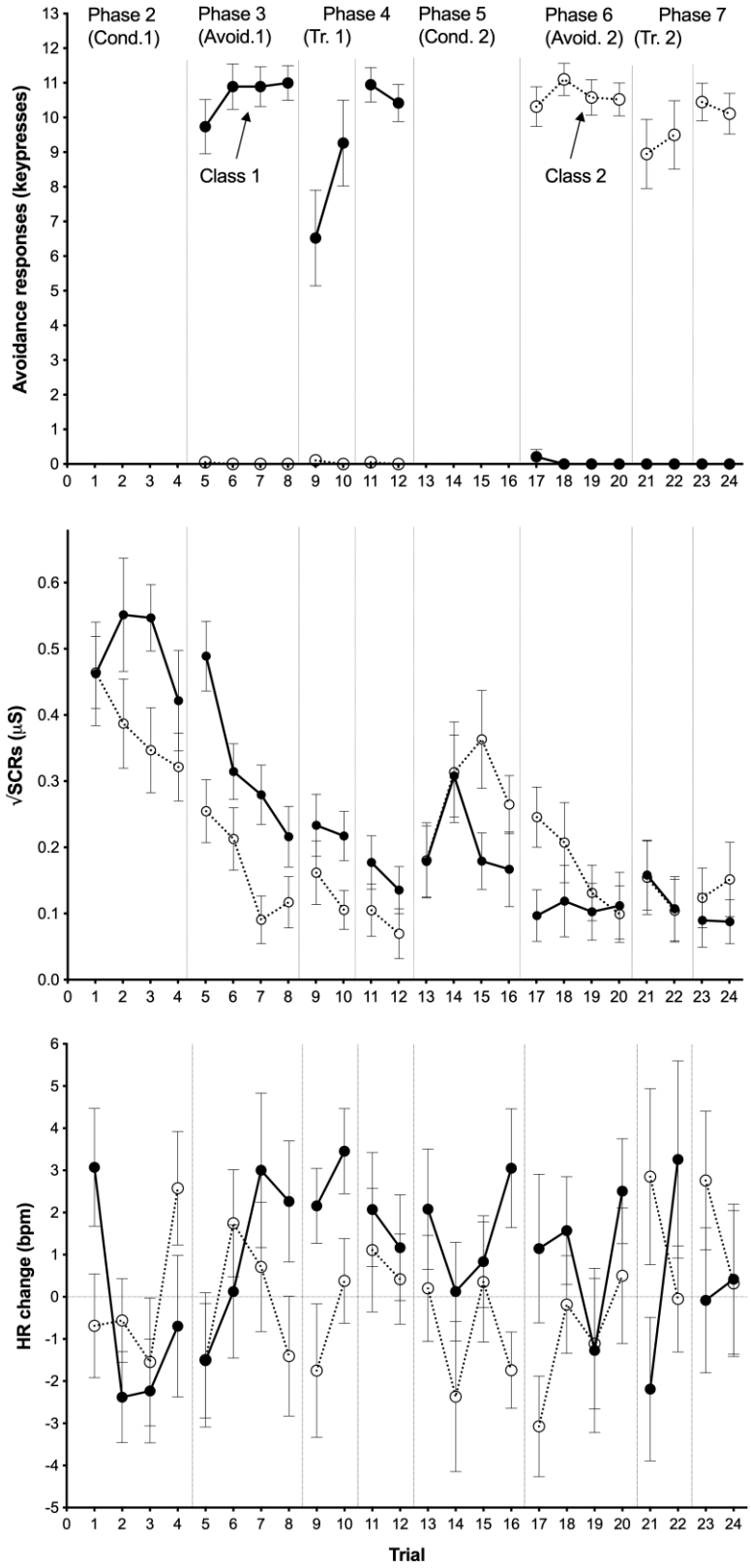


Figure 3.
Group-based results for aversive conditioning, avoidance training, and transfer of function.



Note: Transfer test 1 (Tr. 1) is trials 9 and 10 (Phase 4). Transfer test 2 (Tr. 2) is trials 21 and 22 (Phase 7). Upper panel: Average avoidance responses (± SEM). Middle panel: Average square-roots of skin conductance responses (SCRs) (± SEM). Lower panel: Average heart rate (HR) change (± SEM).

Tables

Table 1**.** Trial types during the equivalence class formation task (correct comparisons bold-highlighted)

Training trials		
A1: **B1** B2 B3	A2: B1 **B2** B3	FEEDBACK
A1: **C1** C2 C3	A2: C1 **C2** C3	
A1: **D1** D2 D3	A2: D1 **D2** D3	
A1: **E1** E2 E3	A2: E1 **E2** E3	
Symmetry trials		
B1: **A1** A2 A3	B2: A1 **A2** A3	NO FEEDBACK
C1: **A1** A2 A3	C2: A1 **A2** A3	
D1: **A1** A2 A3	D2: A1 **A2** A3	
E1: **A1** A2 A3	E2: A1 **A2** A3	
Transitivity/equivalence trials		
B1: **C1** C2 C3	B2: C1 **C2** C3	NO FEEDBACK
B1: **D1** D2 D3	B2: D1 **D2** D3	
B1: **E1** E2 E3	B2: E1 **E2** E3	
C1: **B1** B2 B3	C2: B1 **B2** B3	
C1: **D1** D2 D3	C2: D1 **D2** D3	
C1: **E1** E2 E3	C2: E1 **E2** E3	
D1: **B1** B2 B3	D2: B1 **B2** B3	
D1: **C1** C2 C3	D2: C1 **C2** C3	
D1: **E1** E2 E3	D2: E1 **E2** E3	
E1: **B1** B2 B3	E2: B1 **B2** B3	
E1: **C1** C2 C3	E2: C1 **C2** C3	
E1: **D1** D2 D3	E2: D1 **D2** D3	

Table 2**.** Results of equivalence class formation for each participant. In the columns 'TTC' (trials to criterion) the figures in parenthesis indicate the total number of correct trials. In the columns '% correct', the figures in parenthesis indicate the number of correct trials during the last group of blocks upon which criterion achievement was calculated.

	Training of basic relations		Symmetry		Symmetry/Equivalence		Retest	
	Trials to criterion	% correct	Trials to criterion	% correct	Trials to criterion	% correct	Trials to criterion	% correct
P1	88 (72)	95.3% (61/64)	>500					
	64	100%	64	100%	160 (159)	99.4%	160	100%
P2	200 (148)	95.3% (61/64)	64 (63)	98.4%	160 (159)	99.4%		
P3	80 (67)	95.3% (61/64)	64	100%	160 (159)	99.4%	160	100%
P4	136 (108)	96.9% (62/64)	>500					
P5	104 (84)	95.3% (61/64)	64	100%	160 (159)	99.4%	160	100%
P6	112 (95)	95.3% (61/64)	64	100%	160	100%	160	100%
P7	112 (92)	96.9% (62/64)	64 (63)	98.4%	160	100%	160 (159)	99.4%
P8	144 (94)	95.3% (61/64)	64	100%	160 (158)	98.8%	160	100%
P9	104 (89)	95.3% (61/64)	64	100%	160 (159)	99.4%	160	100%
P10	144 (109)	95.3% (61/64)	>500					
	96 (87)	95.3% (61/64)	240 (217)	95.3% (61/64)	160 (158)	98.8%	160	100%
P11	240 (151)	95.3% (61/64)	64	100%	160 (156)	97.5%	160 (157)	98.1%
P12	344 (189)	95.3% (61/64)	>500					
	64 (61)	95.3% (61/64)	64	100%	160	100%	160 (159)	99.4%
P13	104 (77)	95.3% (61/64)	64	100%	160 (158)	98.8%	160 (158)	98.8%
P14	136 (116)	95.3% (61/64)	64 (63)	98.4%	160 (155)	96.9%	160 (156)	97.5%
P15	240 (167)	95.3% (61/64)	64	100%	160 (159)	99.4%	160	100%
P16	160 (121)	96.9% (62/64)	64	100%	160 (158)	98.8%	160	100%
P17	80 (66)	95.3% (61/64)	64	100%	160 (159)	99.4%	160 (159)	99.4%
P18	96 (74)	98.4% (63/64)	64 (63)	98.4%	160 (159)	99.4%	160 (157)	98.1%
P19	>500							
P20	176 (127)	96.9% (62/64)	64	100%	>500			
	64	100%	64	100%	160	100%		
P21	192 (151)	95.3% (61/64)	64 (63)	98.4%	160 (156)	97.5%	160 (158)	98.8%
P22	160 (123)	95.3% (61/64)	64	100%	160 (158)	98.8%	160	100%
P23	128 (105)	95.3% (61/64)	64	100%	160 (155)	96.9%		
P24	88 (68)	95.3% (61/64)	>500					
	64	100%	64	100%	160	100%	160	100%

Table 3: Summary of the individual results regarding avoidance responding during phases 3, 4, 6 and 7 (TTC= trials to criterion). Shaded rows highlight participants meeting avoidance training and transfer criteria.

	Phase 3 Avoidance training 1					Phase 4 Transfer test 1				Phase 6 Av. Train. 2 (reversal)					Phase 7 Transfer test 2			
	TTC	+ B1	+ C1	- B2	- C2	+ D1	+ E1	- D2	- E2	TTC	+ B2	+ D2	- B1	- D1	+ C2	+ E2	- C1	- E1
P7	8	10	13	0	0	13	13	0	0	8	14	12	0	0	13	15	0	0
P17	20	6	5	0	0	6	5	0	0	8	5	5	0	0	5	5	0	0
P6	8	13	13	0	0	12	13	0	0	8	10	11	0	0	12	11	0	0
P8	8	9	11	0	0	11	11	0	0	8	10	10	0	0	9	10	0	0
P9	20	13	13	0	0	14	13	0	0	16	12	11	0	0	11	12	0	0
P18	8	11	11	0	0	11	10	0	0	8	9	10	0	0	9	11	0	0
P21	8	14	14	0	0	14	15	0	0	8	14	15	0	0	15	14	0	0
P13	8	15	12	0	0	13	14	0	0	8	10	10	0	0	9	11	0	0
P14	8	11	10	0	0	11	15	0	0	8	13	11	0	0	14	9	0	0
P10	8	12	11	0	0	12	10	0	0	8	10	9	0	0	0	11	0	0
P5	8	10	9	0	0	7	0	0	0	8	10	11	0	0	9	8	0	0
P1	12	6	8	0	0	0	0	0	0	8	10	10	0	0	9	10	0	0
P3	8	13	12	0	0	0	13	2	0	8	9	12	0	0	10	11	0	0
P11	8	13	13	0	0	0	12	0	0	8	14	14	0	0	13	15	0	0
P15	8	12	13	0	0	0	12	0	0	8	8	9	0	0	9	9	0	0
P22	8	8	10	0	0	0	9	0	0	8	10	9	0	0	9	10	0	0
P24	8	11	11	0	0	0	11	0	0	8	10	11	0	0	11	11	0	0
P2	8	9	11	0	0	0	0	0	0	8	12	11	0	0	0	0	0	0
P12	8	13	12	0	0	0	1	0	0	8	11	6	0	0	0	0	9	0
P16	8	11	9	0	0	0	0	0	0	8	10	10	0	0	0	0	0	0

Table 4: Summary of the individual results regarding skin conductance responses (µS) during phases 3, 4, 6 and 7. Shaded rows highlight participants meeting differential conditioning and transfer criteria.

	Phase 3 Avoidance training 1				Phase 4 Transfer test 1				Phase 6 Av. Train. 2 (reversal)				Phase 7 Transfer test 2			
	+ B1	+ C1	- B2	- C2	+ D1	+ E1	- D2	- E2	+ B2	+ D2	- B1	- D1	+ C2	+ E2	- C1	- E1
P7	.45	.45	.18	.20	.35	.28	.05	.09	.43	.48	.64	.22	.64	.32	.39	.34
P17	.05	.12	.02	.02	.07	.18	.05	.12	.15	.10	.00	.00	.09	.06	.00	.00
P6	.10	.14	.00	.00	.08	.20	.16	.09	.02	.03	.00	.01	.00	.00	.00	.00
P8	.21	.12	.00	.03	.30	.05	.49	.02	.07	.00	.00	.00	.02	.00	.00	.05
P9	.05	.06	.00	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P18	.04	.14	.02	.00	.09	.30	.11	.03	.04	.00	.02	.00	.00	.00	.00	.00
P21	.03	.02	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00	.03
P14	.29	.31	.24	.33	.00	.23	.25	.00	.09	.19	.02	.47	.41	.60	.42	.53
P10	.10	.27	.05	.00	.00	.11	.02	.00	.00	.00	.09	.00	.00	.06	.00	.25
P5	.09	.22	.05	.09	.09	.07	.02	.02	.00	.00	.31	.02	.05	.21	.00	.06
P1	.07	.00	.00	.00	.06	.03	.04	.00	.00	.02	.00	.00	.00	.01	.02	.00
P3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P11	.02	.07	.00	.00	.13	.03	.00	.04	.00	.00	.02	.00	.00	.00	.00	.00
P15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P22	.13	.07	.05	.05	.07	.15	.06	.13	.02	.04	.01	.04	.02	.02	.01	.00
P24	.01	.00	.00	.00	.04	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P2	.10	.04	.00	.03	.05	.05	.00	.00	.03	.04	.00	.00	.02	.00	.03	.02
P12	.16	.00	.00	.00	.08	.08	.05	.02	.07	.00	.14	.07	.11	.29	.20	.02
P16	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.23	.05

Table 5: Summary of the individual results regarding heart rate change (bpm) during phases 3, 4, 6 and 7. Shaded rows highlight participants meeting differential conditioning and transfer criteria.

	Phase 3 Avoidance training 1				Phase 4 Transfer test 1				Phase 6 Av. Train. 2 (reversal)				Phase 7 Transfer test 2			
	+ B1	+ C1	- B2	- C2	+ D1	+ E1	- D2	- E2	+ B2	+ D2	- B1	- D1	+ C2	+ E2	- C1	- E1
P7	-5.2	-4.85	-1.88	4.81	5.35	4.36	-18.94	9.68	1.62	-6.99	-3.79	-5.53	-1.35	-3.40	5.68	11.04
P17	-2.02	-6.36	-7.3	-4.71	3.92	3.06	-4.83	-8.32	6.36	-6.12	6.13	-3.47	3.14	7.69	1.44	-0.27
P6	3.00	21.62	2.57	9.92	7.26	13.20	9.88	1.37	-4.88	-3.15	-0.97	-8.13	-4.71	-1.82	-7.08	-6.6
P8	.35	-.20	-3.15	-1.69	-1.96	1.56	3.19	3.52	-5.23	-1.35	-1.06	-8.73	-3.27	-2.08	1.05	2.15
P9	-.43	2.36	2.01	3.07	-.16	5.25	1.54	-1.99	-.12	4.04	8.55	.47	5.80	9.01	6.07	-12.09
P18	4.79	-.33	2.98	-2.47	5.08	1.96	3.78	3.38	3.03	8.14	.86	-.56	10.13	5.34	6.42	1.19
P21	8.07	5.99	-1.77	4.71	2.92	5.53	-.31	-1.65	4.60	6.38	-7.66	-.25	-2.26	0.44	-2.34	-1.48
P13	1.17	-1.88	8.00	-5.47	10.36	1.99	-1.49	-1.02	3.69	3.71	5.04	1.66	2.45	-3.47	2.4	-3.79
P14	7.43	-1.86	5.19	-9.24	14.33	-3.73	2.63	.19	-6.20	-4.05	7.39	10.26	14.73	13.22	12.22	2.09
P10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P5	12.86	-6.93	-5.30	7.17	2.54	1.35	-5.80	.29	10.41	6.09	-3.54	3.91	-9.38	19.92	7.43	-3.69
P1	9.39	2.52	.08	-2.95	6.00	-3.84	2.95	-0.85	.77	3.22	2.68	8.07	-2.52	7.78	-4.10	-2.26
P3	12.23	-6.77	1.95	-1.65	2.39	4.17	-6.89	1.26	-11.65	1.55	7.87	4.72	2.72	8.65	-.67	11.61
P11	7.78	11.39	-7.99	-4.36	4.93	2.23	-13.26	-7.19	8.76	.12	-2.27	.55	-8.16	-2.82	3.67	-1.91
P15	8.79	2.18	-3.01	-14.88	-2.78	-3.45	3.20	-.54	13.41	8.52	5.17	-9.04	2.87	-6.17	-5.78	-12.43
P22	-.67	10.17	7.08	-1.94	1.16	-.47	-.86	-.73	-2.15	-7.44	12.43	-3.59	-2.75	11.58	.49	8.35
P24	-7.18	14.77	14.12	-2.26	.34	5.32	4.49	-5.64	-7.61	-6.00	-7.36	8.20	7.91	-1.17	-.53	-22.05
P2	2.56	-2.26	4.17	-6.72	5.03	-.62	-1.99	-1.49	-.86	-13.44	-1.49	9.29	-7.67	1.78	-.74	.20
P12	-5.21	-9.54	-2.29	-5.91	-2.81	1.63	-2.82	-6.25	-7.30	1.88	5.27	-23.76	-2.73	1.33	36.93	0.26
P16	8.41	3.63	14.77	-9.03	2.44	.76	6.96	8.41	3.22	-16.77	-5.25	11.41	1.43	-19.20	-11.59	-1.06